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USSR: Turbines for Natural Gas Pipelines

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A Research Paper

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USSR: Turbines for Natural Gas Pipelines [redacted] 25X1

A Research Paper

This paper was prepared by [redacted] Office of 25X1
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July 1984

USSR: Turbines for Natural Gas Pipelines [redacted] 25X1

Summary

Information available as of 1 June 1984 was used in this report.

During the 1986-90 period, the USSR will probably be much less dependent on the West for gas turbines than in the past, largely because of increased production of industrial gas turbines and a slower pace of construction of large-diameter gas pipelines. We estimate that the Soviets will lay about 12,000 to 14,000 kilometers of 1,420-mm gas pipelines during 1986-90 (compared with 20,000 kilometers during 1981-85) and will be required to install roughly 9,000 megawatts (MW) of turbine power to fully equip them. At the present estimated level of output, nearly 2,100 MW a year, domestic production may be adequate to meet demand for gas turbines with power ratings between 10 and 25 MW. However—on the basis of the history of Soviet gas-turbine development and the opinions of Western turbine experts—we believe that domestically produced gas turbines will prove less reliable and less efficient than Western turbines. As a result, Moscow may continue to import Western turbines on a selective basis, particularly if supplier credits are available on favorable terms. [redacted] 25X1

The Soviets' development of large gas turbines with power ratings of 16 and 25 MW made very little progress during the 1970s. This slow development was the result of the confusion caused by too many design, research, and production groups working on the same problem; the typical bureaucratic turf wars; and the absence of strong pressure from above. Because the Soviets were able to rely to a considerable extent on the West for high-quality turbines, they lacked incentive to cut through the redtape and to develop larger and better turbines themselves. [redacted] 25X1

During the 1970s, the USSR imported nearly 300 Western turbines, accounting for at least one-third of the aggregate power installed on 1,420-mm gas pipelines. These turbines were installed at compressor stations on key gas transmission pipelines. The importance of these Western turbines to the pipeline system was underscored by repeated Soviet requests during the recent US embargo for resumption of spare parts deliveries. [redacted] 25X1
[redacted] 25X1

The US embargo delayed and clearly threatened to lower availability of high-quality, efficient gas turbines and thus reduce Moscow's ability to rapidly bring all of the planned new pipelines to full-capacity operation. The embargo also posed a threat to the operation of Western-equipped compressor stations on existing pipelines. Although we do not have evidence that pipeline operation was hampered by a lack of spare parts, it is likely that some scheduled maintenance was delayed—a factor that could have adverse consequences for the service life of the turbines affected. [redacted] 25X1

When faced with the prospect that the US embargo might delay delivery of 120 Western 25-MW gas turbines ordered for the gas export pipeline, the Soviets made the development of powerful turbines a national economic and political priority. We estimate that the aggregate power provided by annual Soviet production of 10-, 16-, and 25-MW turbines increased from about 1,000 MW in 1981 to 2,100 MW in 1983. [redacted] 25X1

The crash program to produce 16- and 25-MW gas turbines even drew upon the resources of a major defense production ministry—the Ministry of the Aviation Industry. This ministry is devoting plant and personnel resources [redacted] to modify retired NK-8 aircraft engines for use as industrial gas turbines, but this activity is probably not having any major impact on the output of engines for military aircraft. [redacted] 25X1

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Although the embargo motivated Moscow to accelerate development of a production capability for 16- and 25-MW gas turbines, it probably also caused substantial short-term disruption in several branches of industry. Our analysis indicates that the USSR expanded turbine production primarily by diverting existing plant capacity from other uses. We believe the Soviets had to reschedule production of some turbines intended for the electric power and chemical industries; and in addition—even though nuclear power plant construction is behind schedule—major component suppliers for the nuclear power industry were tasked to manufacture parts for gas pipeline turbines. [redacted] 25X1

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USSR: Turbines for Natural Gas Pipelines 25X1

Introduction

Natural gas produced in West Siberia currently accounts for over half of the Soviet Union's gas output. Most West Siberian gas is transported 3,000 to 4,000 kilometers (km) to the European regions of the USSR through 1,420-mm gas pipelines operating at pressures up to 75 atmospheres (atm)—about 1,100 pounds per square inch. To drive the compressors on these long-distance gas transmission pipelines, the Soviets almost exclusively use gas turbines fueled from the pipeline. This operation thus achieves independence from outside energy sources; it does not deplete local supplies of energy in the regions transited. Using electric motors, instead, to power the compressors would create a need for new powerlines in West Siberia and would impose a drain on already heavily taxed power grids in the western USSR. The amount of power required to operate the compressors on 1,420-mm gas pipelines is by no means small. For example, the power required to drive the compressors on the gas export pipeline at full capacity alone would be equivalent to the amount of electricity used by a city with a population of about 2.2 million (the size of Kiev).[1]

During the 1971-80 period, Soviet industry made halting and mostly unsuccessful attempts to develop and manufacture 16- and 25-megawatt (MW) gas turbines for installation on large-diameter gas pipelines. Consequently, the USSR relied on substantial imports of Western turbines and became heavily dependent on a US supplier for spare parts for most of these turbines. The Soviets' primary reaction to the 1981-82 US embargo was a greater effort to perfect and manufacture turbines for large-diameter pipeline service—an effort that had a negative impact on the production of gas turbines for use in other industries.[2] 25X1

Background

The USSR has a history of difficulty in developing and producing gas turbines. During the 1950s, it produced 4- and 6-MW turbines that were large in size and weight and inefficient in fuel consumption. These units were shipped to compressor stations as major subassemblies and required up to two years to install. During the 1950s, the Soviet demand for lightweight, efficient, and more powerful gas turbines was not great: gas production in 1955 was only 10 billion cubic meters (m³), the USSR gas pipeline network was only 4,900 km in length, and the largest pipe in use was 720 mm in diameter. 25X1

Subsequently, Soviet gas output soared—to 46 billion m³ in 1960 and to 200 billion m³ in 1970—as new and productive gasfields were developed in the remote areas of Central Asia and West Siberia. To transport and distribute gas from these areas to the industrial and populous European USSR, the Soviets rapidly increased the length of the gas transmission network, to 21,000 km in 1960 and to nearly 68,000 km in 1970. Moreover, they began to lay large-diameter gas pipelines (1,020 mm and greater in diameter) at an ever increasing pace. During 1961-70 the Soviets

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[1] In 1980 about 80 percent of the aggregate power installed on the USSR gas pipeline network was provided by gas turbines. We believe that nearly all of the compressors powered by electric drive are found on older, smaller pipelines.

[2] Gas turbines are manufactured for various purposes. In this paper, *gas turbine*, unless otherwise stated, refers to the mechanical-drive gas turbine used to drive a compressor on a pipeline. Mechanical-drive turbines are of two basic types: aeroderivative and heavy duty. The aeroderivative gas turbines (derived in large part from retired aircraft engines) are more compact and weigh much less than the heavy-duty turbines. Mechanical-drive gas turbines for gas pipeline service or industrial processes are sometimes referred to as *industrial turbines* to distinguish them from turbines designed for generation of electric power or marine propulsion. 25X1

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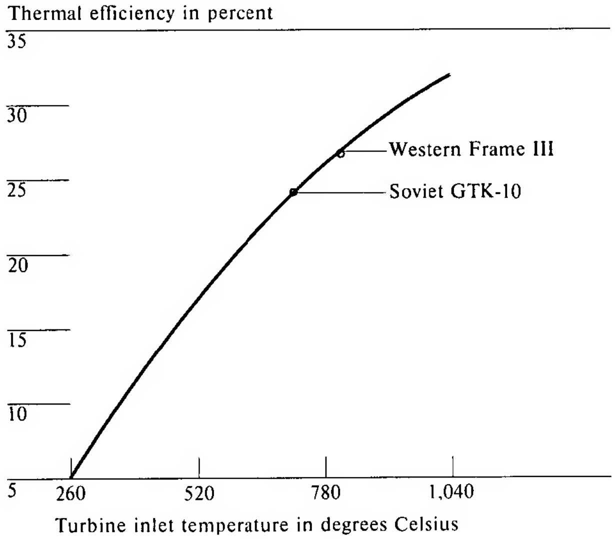
Figure 1
Turbine Inlet Temperature Versus Efficiency[a]



[a] The use of more efficient gas turbines can save up to a billion cubic meters of gas per year per pipeline in fuel consumption.

[redacted]

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installed nearly 21,000 km of 1,020- and 1,220-mm gas pipelines. Recognizing the need for more powerful, less bulky, and more reliable gas turbines for the expanding gas pipeline system, the Soviets instituted a program for development of 10-, 16-, and 25-MW units. [redacted]

By 1970 the turbine program was still progressing slowly. The design of the 4- and 6-MW gas turbines was improved, and a new 10-MW unit, the GTK-10, was developed. The GTK-10, however, was bulky (weighing about 115 tons, or nearly as much as a US-designed heavy-duty 25-MW unit), and the turbine inlet temperature—an important factor affecting efficiency and gas consumption—was about 170 degrees Celsius below the inlet temperature of a US turbine developed at about the same time (see figure 1). [redacted]

[redacted] the alloys used for the blades of the high-pressure turbine of the GTK-10 were similar to the materials employed in US industrial gas turbines developed during the 1950s (see figure 2 for explanation of gas-turbine operation). Thus, the level of technology being applied in industrial gas-turbine development in the USSR during the 1970s was far behind that available in the West. [redacted]

Gas-Turbine Supply for the 1,420-mm Pipeline Program

During 1971-80 the problem of an adequate supply of gas turbines for the gas pipeline network became more complex. As the development of the Central Asian and West Siberian gasfields intensified, it was necessary to keep pipeline capacity commensurate with rapidly expanding gas production. The Soviets began to lay long-distance, 1,420-mm pipelines operating at 75 atm and capable of transporting 30-35 billion m^3 of natural gas annually (see figure 3). The laying of 1,420-mm pipelines was undertaken because of construction economies and operating-cost advantages.[3] [redacted]

To maintain 75 atm of pressure on the 1,420-mm gas pipelines, gas turbines with power ratings of 10 MW and greater were needed. According to Soviet technical journals, smaller turbines are not economical for use on 1,420-mm gas pipelines operating at 75 atm because of the much higher construction costs per unit of power (see table 1). Moreover, the operating expenses per unit of power are approximately 20 percent greater for the smaller turbines than for larger ones (10 MW and above). [redacted]

[3] The net throughput of a 1,420-mm gas pipeline (about 30 billion m^3) is 50 percent greater than the throughput of a 1,220-mm gas pipeline (20 billion m^3) and about 200 percent greater than that of a 1,020-mm pipeline (10-12 billion m^3). Thus, for a given increment in the capacity of the pipeline system, the use of 1,420-mm gas pipelines meant that fewer pipelines and fewer compressor stations would have to be built—and that aggregate capital and labor costs would be lower. [redacted]

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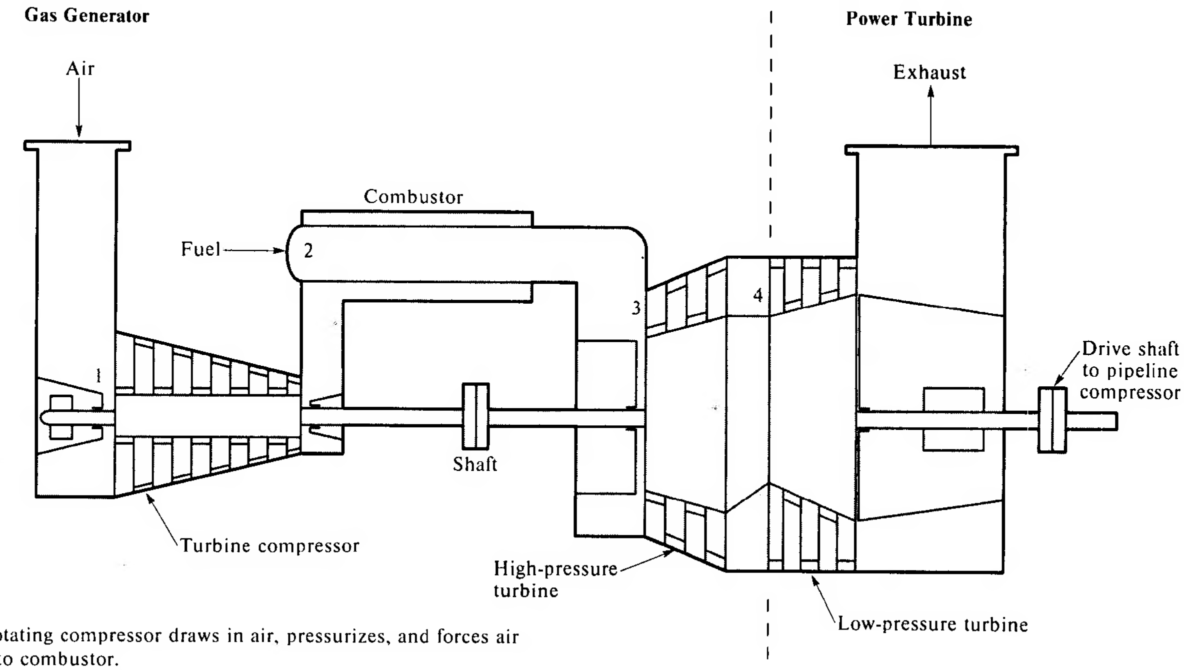
Figure 2
Operation of an Industrial Gas Turbine



1. Rotating compressor draws in air, pressurizes, and forces air into combustor.
2. Fuel is added and ignition occurs.
3. Volume of gas-air mixture expands rapidly and passes across blades of high-pressure turbine, which rotates a shaft that drives the turbine compressor, thus sustaining the cycle.
4. Air-gas mixture passes through high-pressure turbine and across the blades of low-pressure turbine, which is connected by a shaft to the pipeline compressor.

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Development Status of Soviet 16- and 25-MW Turbines, 1971-80

During 1971-80 the development of Soviet 16- and 25-MW gas turbines for pipeline service made little progress. Although some prototypes were assembled, no unit entered serial production. Typically, following the assembly of prototypes, testing was delayed, took a long time to complete, and led to a decision to postpone serial production. Moreover, the urgency of the program to manufacture more and better turbines was sapped by the Soviets' reliance on the West for a large number of high-quality turbines for use on 1,420-mm gas pipelines. The imported turbines provided a "safety valve" that tended to minimize the need for the Soviets to manufacture larger and better turbines. 25X1

We believe that a major obstacle to the successful development of 16- and 25-MW gas turbines was the gas ministry's preference for the more reliable and efficient Western turbines. 25X1

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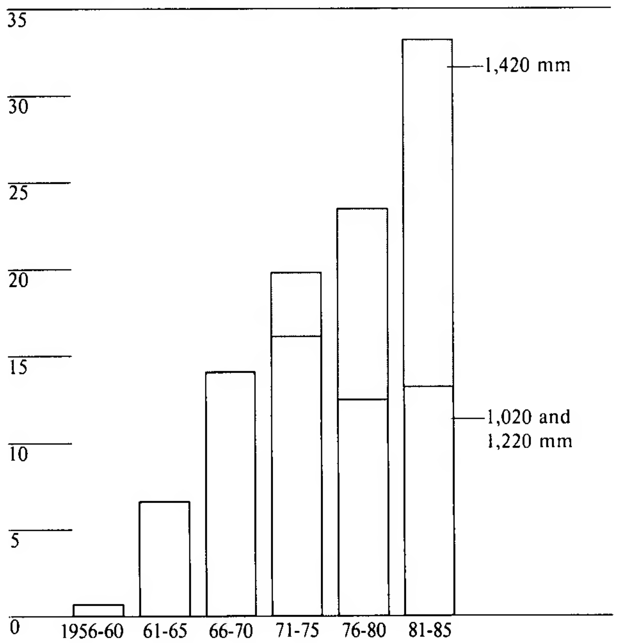
Figure 3
USSR: Installation of Large-Diameter Gas Pipelines (per five-year period)



[redacted]

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[redacted] the gas ministry's preference for Western equipment, together with Gosplan's willingness to finance imports rather than allocate resources to develop domestic versions, was a major hindrance to the development of a Soviet 25-MW gas turbine.

[redacted]

We believe that the decision to import Western turbines and the availability of the domestic 10-MW unit resulted in the assignment of a relatively low priority to the Soviet Union's efforts to develop and

Table 1
Relative Capital Investment Costs for Gas Turbines With Different Power Ratings [a]

Power per Unit (*MW*)	Relative Capital Investment [b] per Unit of Power	Number of Turbines per Compressor Station
6	1.00	NA
10	0.67	8
16	0.54	5
25	0.41	3

[a] For 1,420-mm gas pipeline operating at 75 atm and transporting 30 billion m^3 annually, see S. S. Ushakov, *Ekonomika magistral'nogo transporta gaza,* 1978.
[b] The source does not indicate the actual investment cost for each size of turbine, but rather a percentage of the capital investment that would be required to produce a given amount of power with 6-MW turbines.

[redacted] 25X1

produce 16- and 25-MW gas turbines. The development of 16- and 25-MW gas turbines was slowed by normal Soviet bureaucratic confusion caused by too many design, research, and production groups working on the same problem; the typical bureaucratic turf wars; and the absence of strong pressure from above. 25X1
[redacted] 25X1

In 1980 the Council of Ministers noted that the Ministry of Power Machine Building (MEHM) had facilities for serial production that were inadequate for expanded turbine production and lacked the equipment to produce high-temperature, corrosion-resistant alloys. [redacted] 25X1 25X1 25X1 25X1

Key Role of Western Imports, 1971-80

Soviet press reports indicate that approximately 14,000 km of 1,420-mm gas pipelines were laid during 1971-80. We estimate that the Soviets would have needed to install about 8,800 MW of turbine power

Table 2
USSR: Imports of Western Gas Turbines During 1971-80

Year	Number Imported	Exporting Country	Power per Unit (*MW*)	Aggregate Power (*MW*)
Total	**284**			**3,101**
1972	9	Italy	25	225
1974	65	United States	10	650
1976-80	5	Japan	10	50
	128	West Germany	10	1,280
	35	Italy	10	350
	42	United Kingdom	13	546

[redacted]

during this period—approximately 75 MW of turbine power (including standby capacity) every 120 km of gas pipeline—to operate these pipelines at 75 atm. Soviet technical journals indicate, however, that only 500 GTK-10 units with aggregate capacity of 5,000 MW were installed during 1971-81. We estimate that output of the GTK-10 provided a total of 55 to 65 percent of the power requirements for the 1,420-mm gas pipelines. To service requirements in excess of domestic production, the Soviets turned to the West. [redacted]

Moscow imported at least 284 gas turbines with a combined power of about 3,100 MW during 1971-80 (see table 2). These imports account for about 15 percent of the aggregate power installed on gas transmission pipelines of all sizes during 1971-80. Because nearly all of the imported turbines were installed on major pipelines, we believe that these units may account for a much higher percentage—about 30 to 35 percent—of the 8,800-MW aggregate power requirement for 1,420-mm gas pipelines. Thus, imports of Western turbines during 1971-80 filled a substantial part of the gap that existed between Soviet domestic supply and demand for gas turbines suitable for use on 1,420-mm gas pipelines. [redacted]

The Western turbines were installed at compressor stations along key Soviet gas transmission pipelines. For example, nearly all of the turbines used to power the Soyuz gas pipeline—a major link to Eastern and Western Europe—were imported. Most of the turbines installed on a major pipeline transporting West Siberian gas to the Urals region and another pipeline to Moscow (along the "Northern Lights" corridor) were also imported. [redacted] 25X1
[redacted] about 25X1
one-third of the turbines at two of the USSR's most important compressor station sites—Aleksandrov Gay and Yelets—were imported (see figure 4).[4] [redacted] 25X1

Imports of Western Turbines, 1981-85

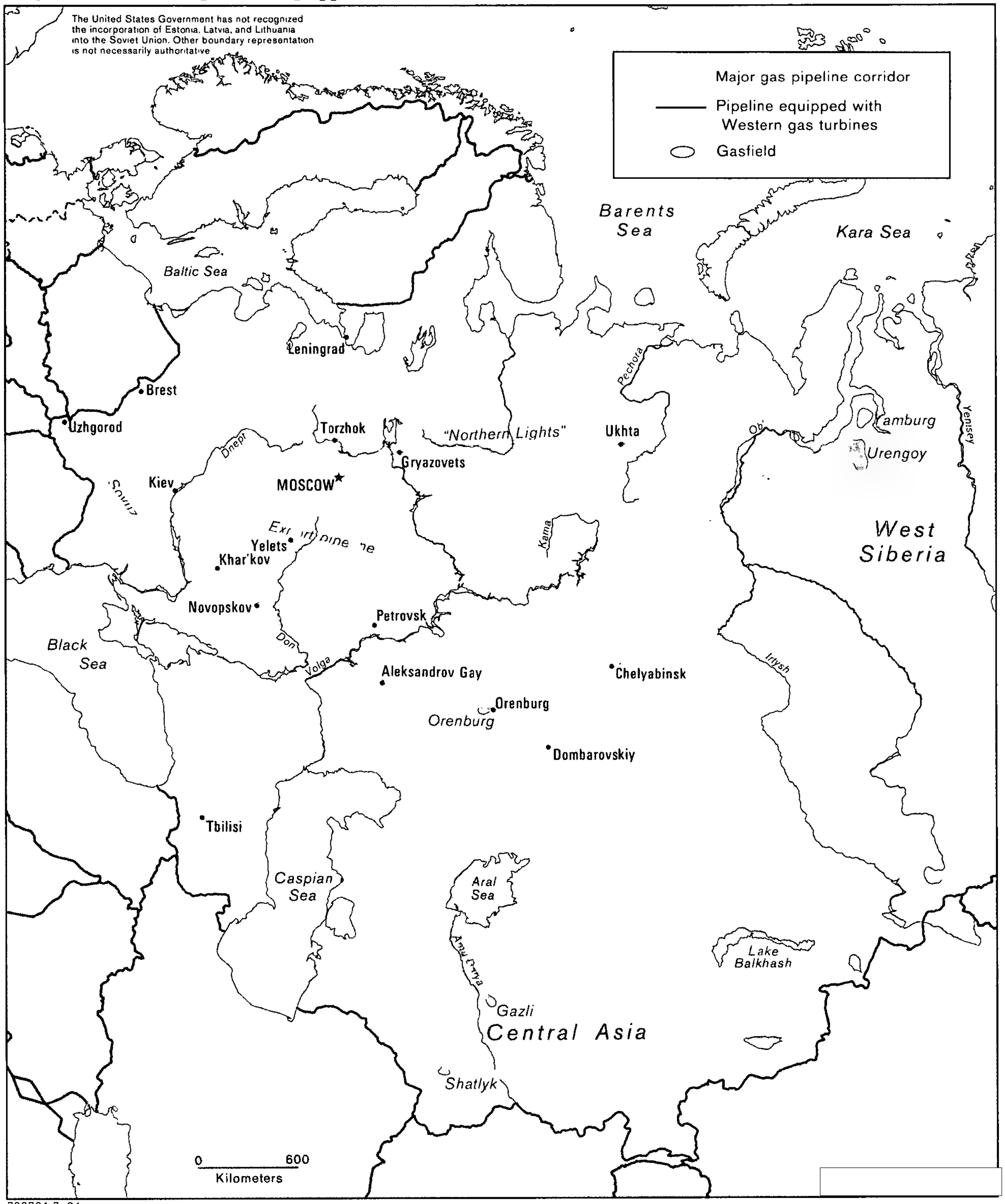
During 1979-82 the USSR negotiated with various West European entities a series of contracts relating to the Siberian–West European gas export pipeline. Several West European gas utilities agreed to new purchases of Soviet gas. The USSR, in turn, agreed to buy pipe and compressor equipment from West European firms for installation on the gas export pipeline. West European banks, with the approval of their respective national governments, arranged financing packages for the Soviet pipe and equipment purchases. Taken collectively, the agreements were popularly viewed as a single deal involving the exchange of gas for pipe and compressors. [redacted] 25X1

The USSR originally contracted with Western firms to buy 120 US-designed Frame V (25 MW) and five US-designed Frame III (10 MW) heavy-duty industrial gas turbines for installation on the 1,420-mm gas export pipeline to be constructed between the Urengoy gasfield and the Soviet export terminal at Uzhgorod.[5] After the United States imposed the embargo in December 1981, however, the USSR committed itself to equipping some of the compressor stations on the gas export pipeline with Soviet turbines—both as a riposte to the US embargo and as a demonstration of Soviet technological progress. On the basis of earlier analysis, we believe that seven

[4] [redacted] in 1979 about 160 billion m^3 of gas annually transited this complex. [redacted] 25X1 25X1

[5] The Frame V turbines were to be built by three West European firms (Nuovo Pignone of Italy, AEG-Kanis of West Germany, and John Brown Engineering of the United Kingdom). The rotor sets for these units were to have been supplied by General Electric (United States). [redacted] 25X1

Figure 4
Major Soviet Gas Pipelines Equipped With Western Turbines



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stations will be equipped with Soviet turbines and that 99 of the 120 originally contracted Frame V turbines will be installed at 33 line stations on the gas export pipeline.[6] (The five Frame III turbines are being installed at the head station at Urengoy.) [redacted]

[redacted]

We believe that the remaining 21 of the Frame V turbines, which were ordered for the gas export pipeline, will be used on at least one of the two major domestic gas pipelines now under construction—the Urengoy–Center I and Urengoy–Center II. The Soviets have also contracted to purchase another 21 Frame V turbines from the Italian firm, Nuovo Pignone. These 42 turbines could fully power 14 compressor stations, considerably enhancing the reliability of those domestic gas pipelines utilizing Western equipment. Altogether, the importation of the 141 US-designed 25-MW turbines will provide the Soviets with about 3,500 MW of turbine power and satisfy about 30 percent of the estimated compressor station power requirement for the pipelines planned for completion in 1981-85. [redacted]

According to information from a Soviet pipeline construction journal, the 1981-85 plan provides for the building of about 180 compressor stations to transport gas through six 1,420-mm gas pipelines at 75 atm (see table 3). To attain maximum throughput on all six of these lines at a pressure of 75 atm, we estimate that the Soviets would have to install approximately 13,000 MW of turbine power—about 75 MW of turbine power per compressor station—during 1981-85.[7] [redacted]

[redacted]

[7] To provide continuity of gas transmission during periods when a turbine is off line for maintenance or overhaul, spare capacity is installed in compressor stations. Thus, in a station using 25-MW turbines, the normal equipment array is two units on line and one in reserve. [redacted]

Table 3
USSR: Major Gas Pipelines Scheduled for Completion During 1981-85

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Gas Pipeline	Number of Compressor Stations	Status (Estimated)
Urengoy-Gryazovets [a]	25	Complete
Urengoy-Petrovsk	24	Complete
Urengoy-Novopskov	30	Nearly complete
Urengoy-Uzhgorod	40	Pipe laid; compressor stations (gas export pipeline) under construction
Urengoy–Center I	30	Pipe laid; compressor stations under construction
Urengoy–Center II	30	Pipelaying started

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[a] Estimate based on one compressor station every 120 km of pipeline, the average distance determined from reported data on the spacing of compressor stations for the five other gas pipelines.

[redacted] 25X1

In addition, the Soviets have recently contracted to purchase an additional 13 US-designed Frame III (10 MW) units from Nuovo Pignone. [redacted] 25X1
[redacted] these turbines will be used to 25X1
increase the throughput of the Soyuz pipeline. The Soviets are also seriously studying the possibility of installing additional UK-built 22-MW gas turbines in 25X1
compressor stations along the pipeline corridor from Urengoy to Chelyabinsk. [redacted] 25X1

The Impact of the US Embargo

The US embargo delayed and clearly threatened to lower availability of high-quality, efficient gas turbines and thus reduce Moscow's ability to rapidly bring all of the planned new pipelines to full-capacity operation. The embargo also posed a threat to the operation of compressor stations on existing pipelines. [redacted]

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Vulnerability Exposed: The Spare Parts Issue

Because of normal wear, certain parts of a gas turbine must be replaced regularly in a preventive maintenance program. Although the USSR has developed a capability to produce some parts for Western turbines, the critical hot-gas-path parts and certain other components must be obtained from Western suppliers. When purchasing equipment from the West, the Soviets normally buy sufficient parts to cover several years' use and set up contracts for subsequent supply. Dependence on imported parts creates a vulnerability to interruption of supply, but, because of the policy of acquiring a large parts inventory, operations may not be affected for a year or more following a supply interruption. [redacted] 25X1

In 1980 a US turbine manufacturer signed a five-year contract to supply spare parts for the 242 US-designed gas turbines (233 Frame III 10-MW units and nine Frame V 25-MW units) operating in the USSR. (A major West German turbine manufacturer dropped out of the business of supplying spare parts for these turbines during the late 1970s.) [redacted] 25X1 25X1

During and immediately after the US embargo, the USSR repeatedly requested that deliveries of spare parts be resumed as soon as possible. [redacted] 25X1 25X1 Although we do not have evidence that pipeline operation was hampered by a lack of spare parts, it is likely that some scheduled maintenance was delayed—a factor that could have adverse consequences for the service life of the turbines affected.[8] The Soviets, in any event, have demonstrated a heightened sense of vulnerability attributable to the US embargo. [redacted] 25X1

[redacted] 25X1

Opportunity Created: Acceleration of Domestic Production

Faced with the prospect that the US embargo might delay delivery of the 120 Western Frame V gas turbines for the gas export pipeline and the fact that—even with these turbines—the existing level of Soviet gas-turbine production would not be adequate to fully equip the five domestic gas pipelines planned during 1981-85, Moscow initiated a crash program to produce 16- and 25-MW turbines. [redacted] 25X1 25X1 Without the impetus of the US embargo, the Soviet effort to produce 16- and 25-MW turbines might have continued to flounder. Instead, we estimate, Soviet industry increased its production of gas 25X1

[8] [redacted] by 1979 the turbines were already badly in need of maintenance and replacement parts. [redacted] 25X1 25X1

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[redacted]

turbines from about 1,000 MW in 1981 to 2,100 MW in 1983 [redacted]

The new effort to produce large turbines for pipeline service entailed some shift in emphasis toward use of aeroderivative turbines. While production of the GTK-10, long the workhorse of the Soviet gas transmission pipeline system, was throttled back to permit an expanded effort on the GTN-16 and GTN-25 heavy-duty industrial units at Sverdlovsk and Leningrad, respectively, facilities were made available at Kazan' Aircraft Engine Plant 16 to convert retired NK-8 aircraft engines into gas generators for the GPA-Ts-16 turbine-compressor set. [redacted]

Gas-Turbine Production Facilities. We have identified eight facilities that are involved in the production of heavy-duty and aeroderivative mechanical-drive turbines for large-diameter gas pipeline service (see table 5). During 1975-82, production floorspace at the gas generator assembly plants for the industrial gas turbines increased only moderately. [redacted]

Table 5
USSR: Facilities for Production of Heavy-Duty and Aeroderivative Mechanical-Drive Gas Turbines [a]

Plant	Function
1. Kazan' Aircraft Engine Plant 16	Converts aircraft engine to gas generator for 16-MW aeroderivative.
2. Khabarovsk Machine Construction Plant	Produces 10-MW industrial gas turbine.
3. Leningrad Nevskiy Plant	Assembles gas generator for 25- and 10-MW industrial gas turbines.
4. Leningrad Turbine-Blade Plant (LZTL)	Produces turbine blades for all types of industrial turbines.
5. Leningrad Metals Plant (LMZ)	Produces power turbine for 25-MW industrial gas turbine and associated pipeline compressor.
6. Leningrad Gas Turbine Plant	Administratively connected to LMZ but primarily manufactures large turbines for power generation.
7. Sumy Machine Construction Plant	Produces pipeline compressor associated with 16- and 6-MW aeroderivative turbines.
8. Sverdlovsk Turbomotor Plant	Produces 16-MW industrial gas turbine.

[a] For large-diameter gas pipeline service.

[redacted] 25X1

[redacted] We do not believe that the production facilities at Sverdlovsk or at Khabarovsk were expanded substantially during 1975-82. Expanded production of pipeline turbines at these plants consequently has displaced some production of turbines for other industries (see section, "The Consequences of Accelerated Turbine Production"). [redacted] production floorspace at the Leningrad Turbine Blade Plant (LZTL) increased substantially during 1975-82. Soviet press reporting indicates that this plant is the sole producer of turbine blades for all types of industrial, marine, and electric power turbines.[9] [redacted]

[redacted]

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GTK-10. The Soviets began production of the GTK-10, a 10-MW heavy-duty industrial gas turbine during the early 1970s. We estimate that this turbine was produced at a maximum rate of about 100 units a year. [redacted] 25X1 in 1979 the Nevskiy 25X1 Plant could produce about 75 to 80 GTK-10s annually. A 1981 Soviet press report [redacted] 25X1 indicated that another plant, the Khabarovsk Machine Construction Plant, had the capacity to produce about 20 GTK-10s annually. [redacted] 25X1 25X1 we estimate that the current annual output of the GTK-10 is about 70 units. [redacted] 25X1

We believe that the output of the GTK-10 was lowered to make room for production of the newly developed GTN-25, a 25-MW heavy-duty industrial turbine. The production facilities at the Nevskiy Plant (which were increased only slightly during 1975-82) are not adequate to sustain simultaneously the earlier production level of the GTK-10 and the scheduled output of the GTN-25. According to Soviet media reports, output at the Nevskiy Plant of the GTK-10 will continue to be scaled down as production of the Soviet 25-MW turbine is increased. [redacted] 25X1

GTN-16. The GTN-16 is a 16-MW heavy-duty industrial gas turbine produced at the Sverdlovsk Turbomotor Plant. Assembly of the first prototype was completed in 1979—the year in which serial production had been scheduled to begin—and testing of the prototype began in 1980. [redacted]

GPA-Ts-16. The GPA-Ts-16 is a 16-MW aeroderivative industrial gas turbine. The gas generator is derived from NK-8-2U and NK-8-4 aircraft engines retired from service on the TU-154 and Il-62 passenger airplanes (see figure 5). A power turbine is added to drive the pipeline compressor. Although the Soviet press reported in September 1982 that the GPA-Ts-16 was "devised and assembled" in six weeks, [redacted] 25X1 25X1 this process could not have been completed in such a short time. Twelve to 18 months are normally required for the redesign of the aircraft engine, and another 12 to 18 months are required to establish the production facilities and work the bugs out of the prototype. The announcement that the turbine was modified in six weeks clearly was propaganda designed to demonstrate Soviet success in thwarting the US embargo: earlier media reports indicate that the redesign began about 1979 and that assembly of the prototype was completed in February 1981. [redacted] 25X1 25X1

Soviet media report that the NK-8 aircraft engine is converted to the GPA-Ts-16 gas turbine by the

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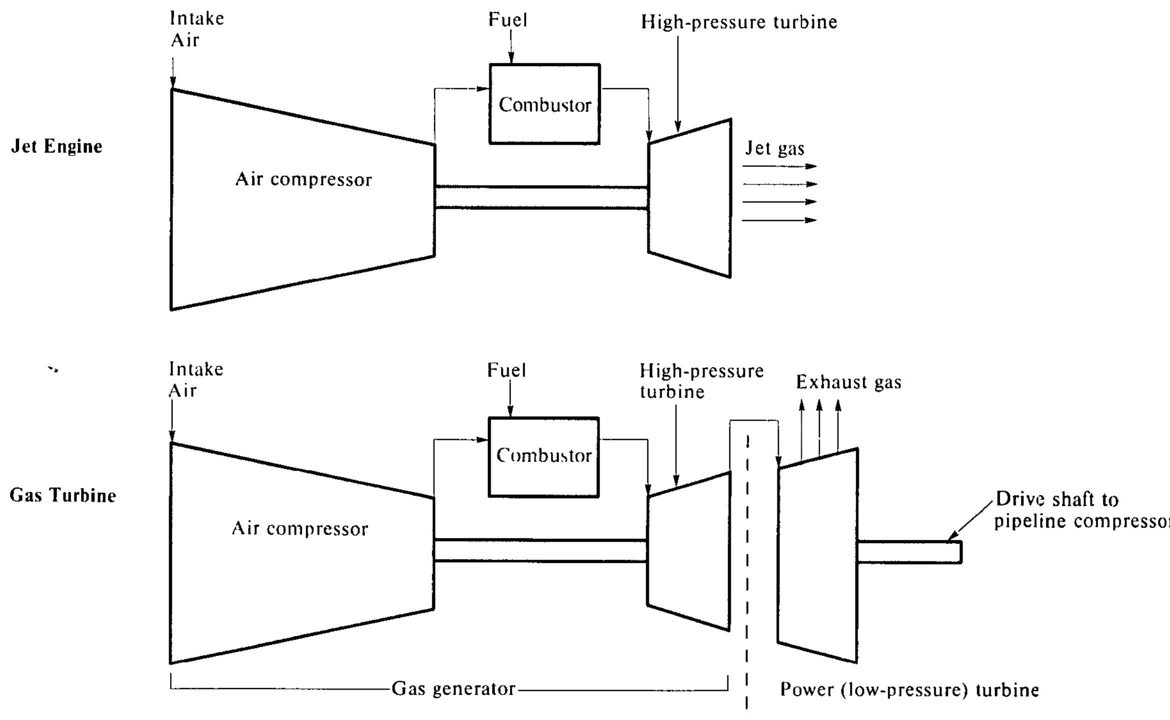
Figure 5
Modification of Jet Engine for Use as Industrial Gas Turbine



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Kazan' Turbomotor Production Association (see boxed text). This association is assigned to the Kazan' Aircraft Engine Plant 16, which is subordinate to the Ministry of the Aviation Industry. Plant 16, the only aircraft engine plant in Kazan', is where the NK-8 was originally manufactured.

The Soviet press has reported that the assembly of 55 GPA-Ts-16 turbines was scheduled for 1983.

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The Soviet Aeroderivative Gas Turbine

We believe that the configuration of the NK-8 aircraft engine is amenable to conversion to an industrial gas turbine. The NK-8 is a two-shaft turbofan engine with a two-stage front fan, a six-stage high-pressure air compressor, a single-stage high-pressure turbine, and a two-stage low-pressure turbine. As an aircraft engine, the two-stage low-pressure turbine rotates the front fan. With conversion to a mechanical-drive turbine, the front fan is removed, and the low-pressure turbine becomes the power turbine to drive the pipeline compressor. (A US turbine manufacturer made a similar adjustment when modifying one of its aircraft engines.) [redacted]

We believe that modification of the NK-8 aircraft engine could produce an industrial turbine with a shaft-power rating consistent with Soviet media reports—16 MW. A UK jet engine manufacturer was able to convert a high bypass (4:1 to 5:1) turbofan engine, the RB-211, with a thrust rating of 42,000 pounds to an aeroderivative gas turbine with a 22-MW shaft-power rating. In aircraft service, with a high bypass turbofan, a large part of the thrust is generated by air passing through the front fan and over (not through) the engine. This power is immediately lost when the front fan is removed and the aircraft engine is converted for mechanical drive. We believe that the Soviets could produce an aeroderivative turbine with a shaft-power rating of 16 MW when modifying the low bypass (1:1) NK-8 turbofan engine, which has a thrust rating of 22,000 pounds. Because of the NK-8's low bypass ratio, the shaft power available from the converted engine is relatively high in relation to the thrust rating of the original aircraft engine. [redacted] 25X1

The conversion of retired aircraft engines is an economical alternative to the design and development of an industrial turbine, which would require long lead-times in design, development, and production. Because the inlet temperature in jet engines is only slightly below the temperature at which the turbine blade and nozzle materials would fail, most jet engines have a short service life. [redacted] 25X1 *lowering the metal temperature by just 100 to 150 degrees Centigrade can increase the service life of the turbine materials by 50,000 hours. Soviet technical journals indicate that the turbine inlet temperature of the GPA-Ts-16 is about 90 degrees Centigrade lower than that of the corresponding aircraft engine. Additionally, aeroderivative turbines are light, powerful, and suitable for modular delivery and assembly. Soviet pipeline construction journals report that the time required to build a compressor station using GPA-Ts-16 aeroderivative turbines is about half that required when using GTN-16 heavy-duty industrial turbines.* [redacted] 25X1

[redacted] On the basis of this information, we believe that output of 50 to 55 turbines a year may well be attainable. We also believe that the availability of retired NK-8 engines is adequate to sustain production of 50 to 55 units annually at least through 1990. Earlier analysis of the production rate of this engine indicates that nearly 400 NK-8 aircraft engines would be available for conversion to mechanical-drive turbines, given that the maximum estimated service life for Soviet civil transport aircraft engines is about 10 years.[10] [redacted] 25X1 25X1

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During the US embargo, the Soviets were forced to consider the possibility that delivery of the Western 25-MW turbines intended for use on the gas export pipeline would be considerably delayed, if not prevented entirely. At the same time, the plan to lay five domestic 1,420-mm gas pipelines during 1981-85 required expanded output of Soviet gas turbines. Soviet production of the two models of industrial gas turbines for large-diameter gas pipeline service, the GTN-25 and GTN-16, was proceeding slowly; consequently, increased output of the aeroderivative turbines may have been judged the only realistic option for bringing about an immediate large-scale increase in gas turbines. We estimate that output of the GPA-Ts-16 will provide about 30 percent of the aggregate power provided by Soviet gas turbines produced for pipeline service during 1981-85. [redacted]

[redacted] parts from the aircraft engine generally can provide 70 to 80 percent of the parts required for the aeroderivative turbine.[11] Thus, conversion of the NK-8 aircraft engine to the GPA-Ts-16 mechanical-drive turbine enables the Soviets to avoid many of the consequences of the inertia and conservatism intrinsic to their industrial product-development process when tasked to manufacture a new product. Moreover, using existing aircraft engine parts helps to avoid some of the problems with priorities, supply bottlenecks, and technological constraints that usually impede the attempts of civilian industry to acquire high-temperature, corrosion-resistant materials. [redacted] 25X1

GTN-25. The GTN-25 is a 25-MW heavy-duty industrial gas turbine that the Soviet press is highlighting as a more efficient substitute for the Western 25-MW turbines ordered for the gas export pipeline. The first model of the GTN-25 was assembled during 1977-79 and was tested during 1979-81. We believe that its performance probably was not satisfactory and that significant changes were required. [redacted] 25X1 25X1 25X1 25X1

[redacted]

[redacted] 25X1

[redacted] the Soviets have substantially redesigned the GTN-25's compressor stage and the high-pressure turbine blades. [redacted] West European power equipment firms probably provided substantial assistance to the Soviets in redesigning rotor components. [redacted] this design is sophisticated and in some ways superior to that of the high-pressure turbine blade of the Western Frame V unit. [redacted] 25X1

The Soviet media claim that 15 GTN-25s were assembled during 1983 but note that the production rate may slow because of a shortage of parts—especially turbine blades. [redacted] the Soviets will install at least 21 GTN-25 gas turbines during 1984. (Most were probably manufactured during 1983). The pace of production through the first nine months of 1983 was reportedly sustained by drawing down the parts inventory. [redacted]

According to media reports, the Soviets are planning by 1985 to halve the size of the labor force devoted to production of the GTN-25. To make this reduction possible, Moscow is probably counting to some extent on the scheduled delivery of rotor components made in Western Europe. [redacted] Moreover, the firm itself is not optimistic about meeting the delivery dates. For these reasons, we do not believe that the production rate of the GTN-25 will be increased substantially during 1984-85. [redacted]

The Consequences of Accelerated Turbine Production

The US embargo motivated the Soviets to accelerate development of their production capability for 16- and 25-MW gas turbines. The plan for the production of the GTN-25 was increased from 14 units during the entire 1981-85 period to 14 units in 1983. The schedule for output of the GPA-Ts-16 was increased from five units in 1982 to 55 units in 1983, and output of the GTN-16 was planned to nearly double in 1983. In stimulating the production of turbines for gas pipeline service, however, the US embargo probably also caused substantial short-term disruption in production of gas turbines and certain components for other industries. [redacted]

Production of additional GTN-25s at the Nevskiy Plant in Leningrad may also have affected output of other investment goods. [redacted] according to Soviet media reports, the Leningrad Metals Plant, which previously specialized in manufacturing turbines for the electric power industry, was tasked following the US embargo to produce parts for the GTN-25. Other media reports indicate that the Soviets were required in the summer of 1982 to reconstruct sections of the Leningrad Turbine Blade Plant to accommodate increased output of the GTN-25. [redacted]

As described in an earlier section, increased output of the 16-MW aeroderivative turbine, the GPA-Ts-16, has been accomplished by drawing on the resources of the Ministry of the Aviation Industry. Before the US

embargo, the development and production of the GPA-Ts-16 was stalled. A 1979 press article indicated that the GPA-Ts-16 was a far better alternative to the GTN-16 and called upon all the ministries involved—including the aviation ministry—to work for its "timely development and incorporation" into production plans. According to media reports, however, only five units were produced in 1982. [redacted]

[redacted]

Reliability and Efficiency of Soviet Turbines
Gas turbines produced by the USSR's civilian industry have never equaled Western turbines in quality and efficiency (see figure 7). [redacted] 25X1 the efficiency of Soviet turbines before 1980 was generally about 24 percent, while that of US turbines was 27 to 29 percent. To operate at the level of efficiency attained by US turbines, the Soviets have had to use a regenerative cycle—increasing substantially the size as well as the cost of the turbine.[15] [redacted] 25X1

Recently published USSR technical journals claim that the newly developed Soviet 16- and 25-MW turbines already equal Western turbines. Given their poor track record in civilian turbine design and production, we doubt that the Soviets could have achieved high reliability and efficiency in such a short period—to attain these standards, the West has required several years. [redacted] 25X1 typically during the first years of production, designs are continually modified and improved and that this iterative process is absolutely essential for optimizing performance. [redacted] 25X1 working the bugs out of a prototype turbine is as much a trial-and-error procedure (requiring time and observation) as it is an engineering design problem. [redacted] 25X1

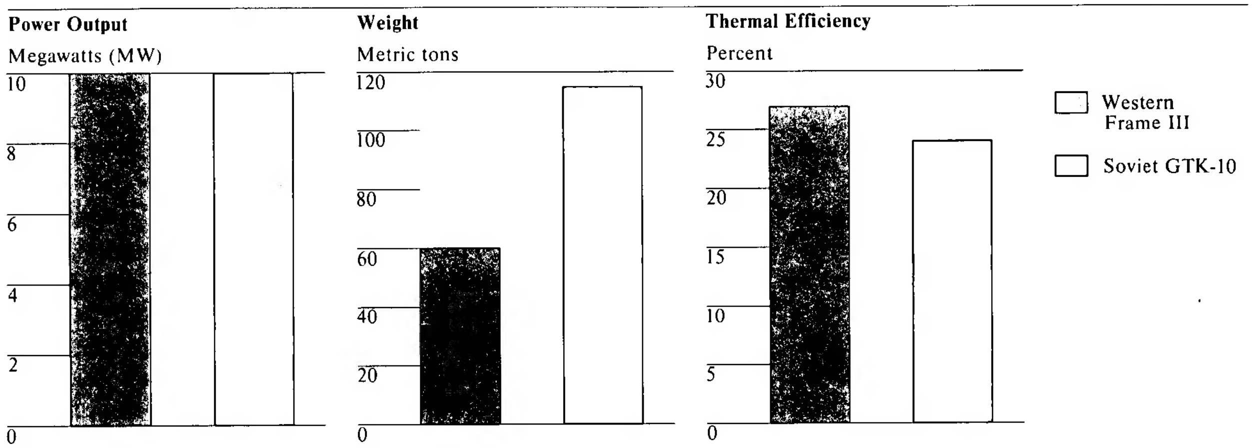
We believe that the new Soviet 16- and 25-MW gas turbines, despite their probable lower efficiencies and (at least initially) poor reliability, are suitable—if imperfect—substitutes for Western turbines. During the first years of operation, they are likely to have a high incidence of failure. As the problems causing these shutdowns are corrected, the reliability of the Soviet turbines (measured as the average time to failure) may improve. [redacted] 25X1

Outlook for Increased Self-Sufficiency

In view of the increased production of gas turbines in the USSR and a likely slowdown in the pace of construction of 1,420-mm gas pipelines, we conclude

[15] A regenerative cycle uses turbine exhaust to add heat to pressurized air entering the combustors. Hotter air entering the combustors requires less fuel to reach the desired temperature, and thus a higher efficiency is achieved. [redacted] 25X1

Figure 7
Comparison of Performance Characteristics of Western Frame III and Soviet Industrial Gas Turbines[a]



[a] Because the Soviets' newly developed 16- and 25-MW turbines have only recently entered serial production [redacted] we have used data for the GTK-10. The Western Frame III turbine, equivalent in power output to the GTK-10, was developed about 20 years before the GTK-10.

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that the USSR during 1986-90 will probably become less dependent on the West for gas turbines. On the basis of previous analysis, we estimate that the Soviets will lay about 12,000 to 14,000 km of 1,420-mm gas pipelines during 1986-90, compared with 20,000 km during the 1981-85 plan period.[16] They will probably lay three or four more pipelines—each about 3,000 to 4,000 km in length—from the Yamburg and Urengoy gasfields to the industrial regions of the country during 1986-90. We estimate that the Soviets will be required to install about 9,000 MW of turbine power to fully equip the pipelines built during this period—about 75 MW per 120 km of gas pipeline. [redacted]

[redacted]

At the present estimated level of output (about 2,100 MW per year), Soviet industry would be able to satisfy nearly all of the 1986-90 demand for gas turbines with power ratings between 10 MW and 25 MW. However—on the basis of the history of Soviet gas-turbine development [redacted] we believe that the Soviet gas turbines will prove to be less reliable and less efficient than comparable Western units. The USSR may continue to import Western turbines on a selective basis, particularly if supplier credits are available on favorable terms. [redacted]

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